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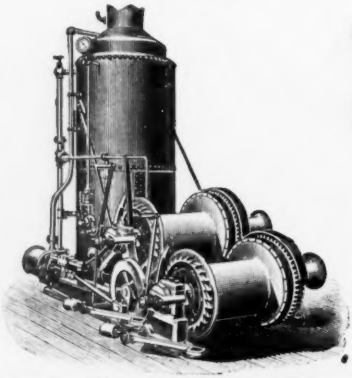

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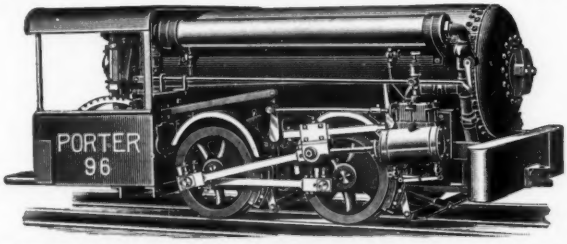

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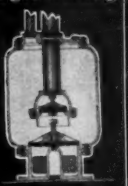

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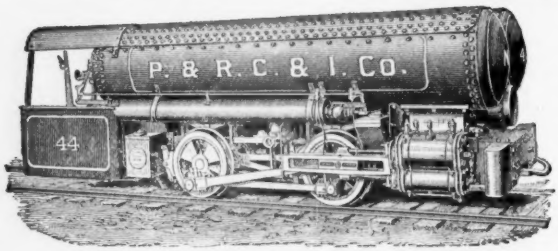

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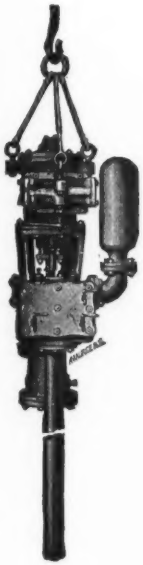

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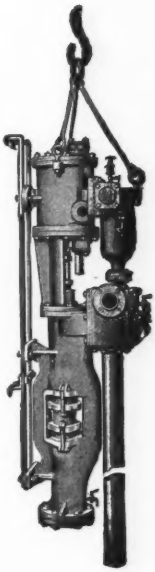

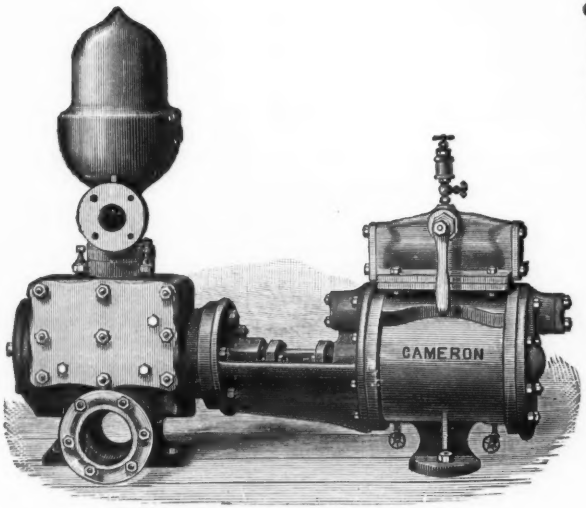

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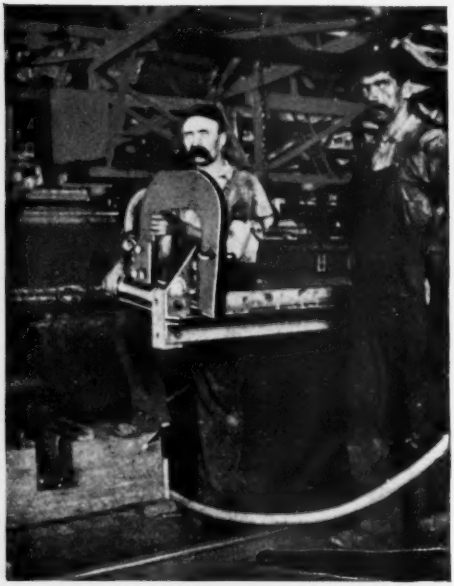

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In considering the practicability of propelling street cars by pneumatic power, we must not lose sight of the fact that for upwards of ten years the Mekarski system, which is strictly compressed air system, has been in use at Nantes, France, and that this system has also been adopted at Berne, Switzerland, and at Vincennes, France. The Popp system, which has recently been installed at Vincennes, is an improvement on the Mekarski system, and is likely to replace it there. There are in this country two systems—the Hardie and the Hoadley-Knight. The American Air Power Company of New York owns all the American rights for these two systems, by virtue of a consolidation of the respective interests, except for the States of Illinois and Wisconsin, where the Hardie patents are owned by a company, of which Mr. H. D. Cooke is president. The European rights under the Hardie system are controlled by the American Air Power Company, but in the consolidation, the so-called Hoadley-Knight patents for Europe, were not included. The Mekarski and the Popp system are known as low pressure systems, the air being stored on the cars at pressures of from 400 to 700 pounds per square inch. The American systems are high pressure systems, the air being stored at from 2,000 to 2,500 pounds per square inch. The Mekarski system has demonstrated clearly, that it is not impracticable or extravagant to use compressed air as a power for tram cars. Mr. Popp in his system has gone further than Mekarski; reducing the weight of the car, and simplifying the machinery. It is plain that the Popp system is in advance of any other French system, and it does not differ very materially from the best American systems.

There is little or no radical difference between the Hardie and the Hoadley-Knight systems; the difference being largely matters of mechanical arrangement, as for instance an English locomotive differs from an American locomotive—the cylinders of one are in a certain place and apply the power of the drivers in a certain way; but both are machines built according to our recognized ideas of steam engineering practice, and both "go" successfully. We might carry this demonstration of the locomotives further, because it really gives a better idea of the points of difference between the two American systems. Hardie applies his power at the wheel of the car, by means of an engine of long stroke, while the Hoadley-Knight system is like the English locomotive, in that the engines are between the wheels, the power being applied through a crank shaft. Compound engines are used in one case, to compensate for the long stroke and early cut-off in the other. The Hoadley-Knight system is more like the best practice with electric motors for tram cars, in that the weight of the motors is partially placed on the car axle.

If we admit, that a practical street car can be, and has been designed, using compressed air as a motive power, the question arises, why is it not generally used for that purpose. The answer to this is, that outside of France, the pneumatic tram car has not, until recently, been favored with that combination of mechanical ability and money, which is essential to the success of any mechanical enterprise. Mr. Franklin Leonard Pope, a distinguished American electrical engineer, now dead, said that compressed air traction would be a success, if there had been spent upon it, even a fractional part of the money and brains, that have been used in the development of electricity, as a motive power for street railroads. Electricity has always been popular as an investment. Its success in the telephone, electric lighting, etc., led capitalists to contribute largely toward its use for street cars, and it was only after many years of work and expense, that the difficulties were overcome. Another obstacle, which has up to this time prevented the more general introduction of compressed air traction, is that it is only recently that we have been able to make a safe, simple and light bottle for storing the air. The storage system has always been aimed at, both in compressed air and electricity, and in order to store sufficient power on the car, it is necessary to provide bottles or reservoirs, which cannot occupy much space, which must be light in weight, and absolutely safe. This has been accomplished in Germany by what is known as the Mannesmann steel tube, which has been adopted generally for this purpose.

The condition of things up to date, is this: Two cars built under Hardie's directions are now running in Chicago, on the North Clark street cable road. These cars are similar to two cars built by Mr. Hardie, and operated for 12 months at 125th street, New York, Third avenue railroad line. Over twenty cars of the Hoadley-Knight pattern have been in operation between three and four months on the Twenty-eighth and Twenty-ninth street cross-town line, in New York city. This plant was installed by the American Air Power Company, but it is under the supervision and has the co-operation of the Metropolitan Street Railway Company, New York. Compressed air for street cars has lately been adopted in Rome, N. Y., the home of the new Hardie motor. These three cases are the only ones, and we cannot safely say, that in either case, the installation has passed entirely beyond the experimental stage. It cannot, however, be said, that compressed air traction is in the experimental stage, in the sense, that one would class automobiles. The difference is this: In street car work the improvements are likely to be in details, matters of construction, saving of expense of repairs, and such like; while with the automobile we may see radical changes in general design, as well as in matters of detail. Compressed air traction is now in a condition where it should appeal to commercial interests, where men, who are in a position to supply the means and get opportunities to place the cars on established roads might make money, provided of course, they employ proper mechanical aid and start in at the point which compressed air traction has reached to-day. The question of comparative efficiency naturally arises. Electricity admittedly is the most successful power for propelling tram cars. It is used extensively for that purpose, and has passed beyond the experimental stages; but it has certain limitations, and this is where compressed air comes in. There are places where it is not permissible to place overhead wires and poles in the street, and this is the present field for the pneumatic tram. In comparing electricity and compressed air for mechanical traction, we must not forget that

the successful electric system is not a storage system. Power is generated at a central station and distributed along the line.

Unfortunately a great deal of time and money has been spent upon the development of an air system on these lines; that is, the lines where electricity is supreme. Engineers now, however, are convinced that the best air system is a storage system, and in this air is superior to electricity. Electric storage for street cars has repeatedly failed because of expense of maintenance, weight of apparatus, time required to charge, and other obstacles, while it must be admitted even by partisans of electricity, that air is easily stored, and that if we are to propel tram cars by the storage system, we may turn to air, as the most practical power for that purpose. Now this introduces between the storage system and the central plant system, which we will not go into here, any further than to say, that it is generally admitted that a good storage system will have a large field. Each car is independent in itself and is its own locomotive. If it is out of order it is taken off and other cars are not interfered with. It does not require expensive track construction. It calls for an inexpensive plant, and there are other conditions, many of which seem to have a strong element that should appeal to the popular idea of successful transportation. We have become accustomed to such things as wires, poles, and slots in the street, while in Europe and in England in particular, the Bus idea seems to be popular. People prefer individual carriages to long trains. The laws restricting placing obstruction in the streets are more rigid, and a compressed air storage system, which calls for nothing more than two rails in the street, should have a better chance than any other.

Three systems of mechanical propulsion are to be considered: 1. The electric overhead trolley; 2, the electric underground trolley; 3, Compressed air. The cost of equipping a line, that is the cost of the plant in overhead trolley and compressed air are practically the same, and it may safely be said, that the cost of operation in both cases is about the same, but that the underground trolley is very much higher in first cost, and the figures of cost of maintenance, including interest account, etc., will favor compressed air; so that in one case the champions of air may meet the overhead trolley system under equal conditions of cost, and without the obstructions in the street, and when competing with the underground trolley, compressed air has the advantage of lower cost. In connection with this important matter of expense the only undetermined point, so far as the compressed air system is concerned, is the question of durability of apparatus, but as all the machinery is built according to common steam engine practice, and as in the score of cars installed on the 28th and 29th street lines, in New York, the car engines are encased free from dust, and running in oil, the question of durability does not appear to be a serious one. Even in this it has to compete with the electric engine and attachments, which are mostly of copper, while the air engine is all steel and iron. In the Hardie car service on 125th street, New York, the average cost per car mile with a two car service running 156 miles per day, was about 20 cents. Of this item coal and water represented about one-quarter, the principal cost being for power plant labor, conductor and motorman, 20 cents per car mile is not high for a two car service, and might be reduced one-half in a large installation.

Theoretical

Discharge of Air from Pipes under Heavy Losses of Pressure.

By William Cox.

It is generally supposed that the volume of "air" discharged from a pipe increases with every increase of pressure absorbed in overcoming friction. Thus, if the initial pressure is 100 pounds, more air will discharged with a final pressure of 80 pounds than with a final pressure of 90 pounds. That a limit to this useful absorption of pressure exists hardly seems to have been considered, except such limit as would be imposed by the extra consumption of fuel, etc. Yet upon due reflection it would almost appear natural that such a limit should exist; but why, where? The important question therefore arises: What, if any, maximum proportion of the initial pressure may in any given case be absorbed in overcoming friction in the pipe before this limit, if it exists, is reached?

One great difficulty in dealing with all problems relating to the flow of air in pipes is that all the practical users of this valuable commodity always calculate according to volumes of free air. Now, free air does not circulate in pipes, does not run rock drills, pumps, hoisting engines, etc. Hence much confusion of ideas. The supposition that free air flows through a pipe implies that there is in it constant volume, constant density and constant velocity of flow. But the fact is that each of these is varying at every step of the current's passage. This general consideration of free air instead of compressed air leads also to the application to it of laws which affect compressed air, whereas the laws governing free air and compressed air, as specially related to flow in pipes, are in most cases entirely opposite.

In order to have clear ideas on this subject, and to arrive at correct conclusions, it is therefore necessary that we should deal with what actually flows through a pipe and is discharged from it. Thus, to return to the supposition with which this paper opens, that 100 cubic feet of air, compressed to 100 pounds gauge pressure, enter into a pipe per minute from the receiver, it would appear evident that with every subsequent reduction of the terminal pressure, or pressure of discharge or egress from the pipe, the volume of air (compressed) discharged will by reason of its expansion be greater and greater until the maximum reduction of the terminal pressure (in this case 100 pounds) expands it to the point of free air, or air at atmospheric pressure, when its volume will also be a maximum. Such increases for a constant volume of compressed air, and for various reductions of pressure would be as follows:

Table I.

100 cubic feet of air at 100 pounds gauge pressure is equivalent to 121 cubic feet at 80 pounds; 153 at 60 pounds; 209 at 40 pounds; 330 at 20 pounds; 464 at 10 pounds and 780 at atmospheric pressure.

As the volume increases therefore toward the outlet of the pipe, the velocity of flow must also clearly increase; and as the greater volume is under a lower pressure, its density must consequently be less, hence as stated, what flows through a pipe is by no means free air.

The assumption, when applied to compressed air, that the volume of air discharged from a pipe increases with every increase of pressure absorbed in overcoming friction, is therefore, we may say, correct. The case given above does not, however, represent the flow of air in a pipe, as it supposes that the same volume of air enters the pipe, and consequently that the same equivalent volume of air, but at a lower pressure, is discharged from the pipe, whatever variations there may be of the terminal pressure.

The laws governing the flow of air in pipes show that the discharge of air (compressed, not free,) from a pipe varies as the square root of the loss of pressure, when the diameter and length of the pipe and the initial pressure are constant.

The formula for the flow of compressed air in pipes given by the writer in Compressed Air, January, 1898, page 359, is:

$$\left.\begin{matrix}\text{Discharge in cubic}\\ \text{feet per minute.}\end{matrix}\right\} = c\sqrt{\frac{d^5 \times (p_1 - p_2)}{w_1 \times l}} \quad (1)$$

which may also be put in the form

$$\text{Discharge} = \frac{c\sqrt{d^5}}{\sqrt{w_1} \times \sqrt{l}} \times \sqrt{p_1 p_2} \ldots\ldots\ldots (2)$$

The first factor on the right hand of this equation represents the diameter and length of pipe and the initial pressure, and if in any number of cases this is a constant quantity, then clearly the discharge of compressed air will vary as $\sqrt{p_1 - p_2}$, or the square root of the loss of pressure. And examination will show that according to the formula there is no limit to this absorption of pressure until the air is discharged without pressure into the atmosphere. But then *cui bono?* Considerations commercial, mechanical or scientific, or all combined, will find it essential that some limit to such watseful absorption of pressure be imposed; and the cost of compressed air at its initial pressure, and its effective value at any given terminal pressure will be in a broad sense the factors which will determine at what figure this limit shall be placed.

In the example of the discharges given in Table I., supposing that

$$\frac{c\sqrt{d^5}}{\sqrt{w_1} \times \sqrt{l}} = 100^*$$

then we should have the following volumes of compressed air discharged at the different terminal pressures noted, namely

Table II.

80 lbs. final pressure,	$100 \times \sqrt{20} = 447$	cu. ft.
60 " " "	$100 \times \sqrt{40} = 632$	"
40 " " "	$100 \times \sqrt{60} = 775$	"
20 " " "	$100 \times \sqrt{80} = 894$	"
10 " " "	$100 \times \sqrt{90} = 949$	"
Atmospheric "	$100 \times \sqrt{100} = 1000$	"

But by table I. we see that 100 cubic feet of air at 100 pounds pressure is the equivalent of 780 cubic feet of free air. Now, if the air were at atmospheric pressure at the exit or in the nozzle of the pipe, it would not flow out of it, as the front and back pressures would balance each other, and the whole volume of air in the receiver would remain there, being balanced by the pressure absorbed in the pipe to overcome the enormous friction produced by the great velocity of flow at the end of the pipe. To force it out, therefore, the pressure in the receiver would have to be increased, and likewise the initial pressure in the pipe, which would then be shown by a somewhat increased volume of $\sqrt{w_1}$ in Eq. (2).

* *This is correct for a 3 inch pipe, 744 feet long, with p_1=100 pounds.*

Or may it not be that if the pressure in the receiver is kept constantly at 100 pounds, that a somewhat less quantity of air would be discharged from the pipe than 1,000 cubic feet? Unfortunately in this examination we have only a theoretical expression of the laws of nature, in the shape of a formula, to guide us, and no series of data based upon actual experiments to help us.

This is, however, taking a very extreme case, where such refinements of calculation would probably never be required, and also one to which perhaps the formula, although an excellent one, may not apply. But it must be remembered that the formula does not deal with the quantity of air that enters into the pipe, but only with what is discharged from it. The first factor on the right hand of equation (2) does not indicate what volume of air would enter the pipe except theoretically upon the supposition that no friction whatever exists. It is only when in conjunction with the second factor that the volume of air discharged is obtained. It may, therefore, be that the real discharge at atmospheric pressure would be 1,000 cubic feet, as also at 90 pounds final pressure 949 cubic feet, and so on.

D. K. Clark, in his work on the steam engine, says: "The flow of steam of a greater pressure into an atmosphere of a less pressure increases as the difference of pressure is increased, until the external pressure becomes only 58 per cent. of the absolute pressure in the boiler. The flow of steam is neither increased nor diminished by the fall of the external pressure below 58 per cent. of the inside pressure, even to the extent of a perfect vacuum."

Is it not possible that some such law may be found to exist in the case of compressed air? Be this as it may, the formula seems to show that the discharge of compressed air continues to increase with every successive reduction of the final pressure, or increase of pressure absorbed in friction, although this increase of discharge is a continuallly decreasing one in proportion to the increase of pressure loss. Thus for 20 pounds loss of pressure, from 80 to 60 pounds final pressure, there is an increase of discharge of 185 cubic feet, whereas for 20 pounds loss of pressure, from 20 pounds final to atmospheric pressure, there is a gain of only 106 cubic feet.

But what interests the compressor builder and, in accordance with the way he has been educated, the compressed air user, is the amount of free air which is supposed to be discharged from the pipe. The compressor builder and user figure only on free air because the compressor at the very commencement of the cycle of operations for which air is to be used, takes in free air, and its dimensions, speed, etc., have all reference to this quantity of free air taken in. So, further on in the cycle of operations, the builder calculates that a given quantity of free air will be required to run a certain number of rock drills, or a hoisting engine, or a pump, or to perform some other work. Therefore as much as possible the views of the builder and user have to be met. That form of the formula which deals with equivalent free air will therefore now be examined.

(To be continued.)

Reheating Compressed Air with Steam.

Clarence R. Weymouth.

In the operation of motors by compressed air it is possible to bring about a considerable saving in the amount of air required in a given case by heating the air.

This heating, or reheating as it is generally termed, may be accomplished in a variety of ways, generally by some form of furnace or combustion heater. In certain cases, if compressed air is heated before entering the motor, a considerable increase of power and efficiency results.

In certain classes of work it becomes convenient to reheat the air with steam by either of the following methods:

First—A pipe from the boiler discharges steam into the air main and the mixture is carried into the cylinder of the motor.

Second—Air is passed through the boiler, either up through the water or simply through the steam space over the surface of the water, and becomes mixed with and heated to the temperature of the steam.

The accompanying tables show the results obtained with these two forms of reheating and will prove of value to those interested in the important problem of efficient reheating of compressed air.

In calculating these tables one pound of air was assumed as the unit. The weight of steam to heat the air to any given temperature, and the final temperature after adiabatic expansion of the mixture to atmospheric pressure was determined. Then from the initial and final conditions of the mixture, and the properties of the adiabatic, the work of expansion and other desired relations were calculated.

Dalton's law states that the pressures exerted by a mixture of gases or vapors is equal to the sum of the pressures exerted by the individual gases or vapors. Thus at 212° F. steam exerts a pressure of 14.7 lbs. per square inch absolute. A pound of air at 212° F., occupying 10 cubic feet, exerts a pressure of 24.8 lbs. sq. in. absolute.

If this cubic foot tank is also saturated with steam at 212° F. the total pressure exerted will be the sum or

$$14.7+24.8=49.5 \text{ lbs. sq. in.}$$

In the present problem steam is saturated and its pressure is found from its temperature in steam tables.

The air pressure is found from the equation $PV=RT$, and the total pressure is the sum of the two, thus determined.

The following notation will be used:

n=pounds of steam mixed with one pound of air.

Ps=pressure per sq. in. absolute, corresponding to temperature of steam.

t, q, p, x, j, s, p. etc., the corresponding steam quantities as found in Peabody's "Tables of Properties of Saturated Steam."

Pa=the "air pressure" lbs. sq. in. absolute in mixture, according to Dalton's Law.

V=specific volume of air.

R=gas constant.

P_0=initial air pressure in main.

t_0=initial air temperature in main.

Cv=specific heat at constant volume.

Cp=specific heat at constant pressure.

$P=Pa+Ps$=total pressure lbs. sq. in. *absolute.*

Denote conditions after heating by subscript 1, and after expansion by subscript 2.

Steam Discharged into Air Main.

Assume boiler and receiver pressures equal and neglect kinetic energy of motion. Suppose (n) pounds of steam separated by

a circular diaphragm in the air main from one pound of air, both air and steam being separated from the rest of the air by two sliding pistons.

The volume occupied by the steam is ns; volume occupied by air is v_0; volume occupied by both air and steam is—$ns+v_0$. Remove the diaphragm, allowing steam and air to mix intimately, assuring finally a common temperature t_1; the pistons moving out under constant pressure p_0, finally enclose a total volume v_1. The steam, of course, cools to a temperature t_1, causing some condensation. The final weight present, as steam, is nx_1.

From the energy relations the loss of heat by mixture equals the work of expansion against pressure in air main. Hence,

$$n\,(q+p-q_1-x_1p_1)-Cv\,(t_1-t_0)=$$
$$Ap\,(v_1-v_0-ns);\ A=\frac{1}{779};$$

but, $v=\frac{RT}{144\,P_0}$; $v_1=\frac{RT_1}{144\,Pa_1}=ns_1x_1=\frac{nx_1}{p_1}$;

and, $pa_1+ps_1=P_0$.

Making these substitutions and solving for n.

$$n=\frac{Cv\,(t_1-t_0)+144\,AR\,p_0\left\{\frac{T_1}{(p_0-ps_1)}-\frac{T_0}{p_0}\right\}+\frac{RT_1\,p_1\,P_1}{144\,(p_0-ps_1)}}{q+p+144\,Aps-q_1}$$

With but a very small approximation, $\lambda-q_1$ may be substituted for the denominator, and substituting numerical values we have finally,

$$n=\frac{.1692\,(t_1-t_0)+.0683\,p_0\left\{\frac{T_1}{p_0-ps_1}-\frac{T_0}{p_0}\right\}+\frac{.3694\,T_1\,p_1\,P_1}{p_0-ps_1}}{\lambda-q_1}$$

Adiabatic Expansion of the Mixture.

By adiabatic expansion is meant that no heat is given to or taken from the mixture although during expansion there may be a flow of heat between steam and *air*.

Since $p=pa+ps$,

$$p\,dv=pa\,dv+ps\,dv.$$

For an adiabatic $dQ=o$.

$$dQ=Cv\,dt+n\left\{dq+d\,(xp)\right\}+Ap\,dv$$
$$=Cv\,dt+Apa\,dv+n\left\{dq+d\,(xp)\right\}$$
$$+Aps\,dv=o.$$

But—$n\left\{dq+d\,(xp)\right\}+Aps\,dv$ may be reduced to, $n\left\{dq+Td\left(\frac{xr}{T}\right)\right\}$

$$\therefore\ c\,dt+Apa\,dv+n\,dq+n\,d\left(\frac{xr}{T}\right)T=o$$

divide by T,

$$c\,\frac{dt}{T}+Apa\,\frac{dv}{T}+\frac{n\,dq}{T}+n\,d\,\frac{xr}{T}=o$$

Integrate,

$$c\,lu\,T+\int Apa\frac{dv}{T}+\frac{\int n\,dq}{T}+\frac{n\,xr}{T}=K$$

$$\frac{\int Apa\,dv}{T}=AR\,lu\,v-\frac{\int n\,dq}{T}=\frac{n\int dq}{T}=n\,J$$

Then,

$$c\,loge-T+AR\,lu\,v+nJ+\frac{nxr}{T}=\text{Con'st.}$$

Also—$x=\frac{RTP}{144\,(p-ps)}$ $\frac{nxr}{T}=\frac{RPP}{144\,(p-ps)}$

Making Numerical Substitutions and Applying Limits.

$$.5469\,log_{10}T_1-.1573\,log_{10}\,(p_1-ps_1)+\frac{.3694\,r_1p_1}{p_1-p_1s}+nJ_1$$
$$=.5469\,log_{10}T_2+.1573\,log_{10}\,(p_2-ps_2)+\frac{.3694\,r_2\,p_2}{p_2-p_2s}+nJ_2.$$

In this equation T_1, p_1, ps_1, r_1, p_1, J_1, p_2 are generally known.

T_2 is unknown, as are the other quantities, which are direct functions of T_2.

The equation can only be solved by the long and tedious method of trial and error, and then only approximately.

Work done by Adiabatic Expansion of the Mixture.

Proceeding by the usual thermodynamic method, draw an indicator diagram for an ideal engine expanding one pound of air and n pounds of steam to atmospheric pressure, and call this work W.

In Fig. 1 let W=area $abcf$.

W_1=area $bcde$;

W_2=area $oabe=144\div p_1v_1$;

W_3=area $ofed=144\div p_2v_2$.

Then $W=W_1+W_2-W_3$.

Table I.

Reheating Compressed Air with Steam.

Results for Adiabatic Expansion of Mixture from 60 Lbs. Gauge.

Initial Temperature of Mixture.	Pounds of Steam per Pound of Air.	Volume of Steam before mixture.	Volume of Mixture.	Ratio :— Vol. of Mixture. Vol. of Air.	Per cent. of Steam condensed by Mixture.	Final Temperature of Expansion.	Final Volume.	Total Work in ft. lbs. done by Mixture, with Adiabatic Mixture.
150	.0515	.365	3.178	1.23	32.4	32.°	12.5	50,500.
170	.0778	.552	3.390	1.32	29.5	71.8	13.7	52,500.
190	.1175	.801	3.677	1.43	23.2	101.	15.1	58,000.
210	.1798	1.275	4.090	1.59	17.5	124.6	17.	64,400.
230	.2818	2.000	4.733	1.84	12.5	145.3	19.6	74,600.
250	.4684	3.326	5.855	2.27	8.4	164.	24.3	93,300.
270	.8741	6.203	8.242	3.2	5.	181.5	34.2	122,800.

Initial Temperature of Mixture.	Number of Expansions.	Final per cent. of Condensed Steam.	Per cent. increase of work due to Steam.	Rate of increase in lbs. of Steam per I. PP. hr.	Lbs. of Steam per B. PP. hr. with 25 per cent. loss.
150°	3.9	92.	34.	7.96	10.6
170	4.05	78.	39.	10 4	13.9
190	4.1	63.	54.	11.5	15.3
210	4.15+	48.	71.	13.4	17.8
230	4.15+	36.	98.	15.	20.1
250	4.15+	27.	147.	16.8	22.4
270	4.14	18.	226.	20.4	27.2

In the above it is assumed that Steam is fed to the air main by a separate pipe-boiler pressure and air pressure being 60 lbs. gauge.

Condensed Steam is supposed to be carried into the cylinder by the mixture.

By Adiabatic Expansion is meant that no heat is given to or taken from the mixture.

1 lb. air at 60° F., 60 lbs. gd, occupies 2.576 cu. ft. and gives 37,700 ft. lbs. with adiabatic expansion.

2-8-99. C. R. WEYMOUTH.

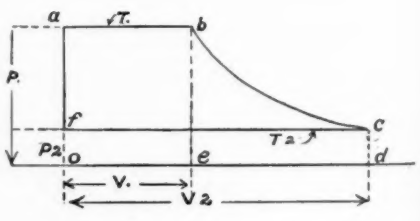
Since the curve bc is an adiabatic, W_1 is equivalent to the loss of heat from b to c.

The heat present at b_1—heat present at a_1 equals W_1.

$$\therefore\ W_1 = 779 \left\{ (q_1 + x_1 p_1) - (q_2 + x_2 p_2) + cv\,(t_1 - t_2) \right\}.$$

As shown above, $x = \dfrac{RTP}{144\,n\,(p - ps)}$;

also, $v = \dfrac{RT}{144\,(p - ps)}$. Making these substitutions,



$$W_1 = 779 \left\{ n\,(q_1 - q_2) + \frac{RT_1 p_1 p_1}{144\,(p_1 - ps_1)} + cv\,(t_1 - t_2) - \frac{RT_2 p_2 p_2}{144\,(p_2 - ps_2)} \right\}$$

$$W_2 = \frac{144\,p_1 RT_1}{144\,(p_1 - ps_1)} = \frac{RT_1 P_1}{(p_1 - ps_1)};\ \text{also,}$$

$$W_3 = \frac{RT_2 P_2}{(p_2 - ps_2)}.$$

Table I gives the approximate results of calculation from the above formulas, when both the boiler and air pressure are 60 lbs. gauge. Various initial temperatures are assumed to which the mixture is reheated, corresponding to which the weight of steam and other quantities are calculated.

The increase of work due to reheating is the gain over the work of adiabatic expansion from 60° F. The rate of increase of work is given in pounds of steam per indicated horse power per hour; also, the steam per brake horse power per hour assuming 25 per cent. loss.

Reheating by Passing Air through a Steam Boiler.

In this case, the pressure in the boiler is also the receiver pressure, and a pound of air is assumed to leave the boiler with n pounds of dry steam, both having the temperature of water in the boiler.

The heat supplied by the boiler is in addition to that of the steam, the amount necessary to raise the temperature of and expand the air.

Suppose air and water supplied to the boiler at the temperature t_0, while the boiler is maintained at the temperature t_1. The initial volume of one pound of air and n pounds of water is $v_0 + no$ cu. ft. The final volume at temperature t_1 becomes $v_1 = ns_1$. Hence, the heat equivalent of external work becomes $144\ Ap_0\ (v_2 - v_0 - no)$.

Heat added to air $= cv\ (t_1 - t_0)$.

Heat added to steam $= n\ (q_1 + p_1 - q_0)$.

Table II.

Reheating Compressed Air with Steam.

Air is passed through a Steam Boiler and the Mixture works with Adiabatic Expansion.

Initial Temperature of Mixture.	Pounds of Steam per pound of Air.	Final Temperature after Expansion to Atmosphere	Final Volume Cubic Feet.	Ratio of Final to Initial Volume of Mixture.	Per cent. of Steam Condensed by Expansion.	Work done by Mixture—ft. lbs.	Per cent. Increase of Work by Steam.	Total B. T. U. supplied by Boiler per lb. of Air.—Feed at 60° F.	Thermodynamic Efficiency of Reheating.
Receiver Pressure 60 Lbs. Gauge.									
150°	.03276	32.°	12.46	3.92	88.78	47,480.	25.9	57.4	21.9
190°	.09027	99.75	15.04	4.09	53.28	57,740.	53.2	131.3	19.5
230°	.24648	144.8	19.55	4.13	27.69	74,440.	97.4	319.3	14.8
270°	.83078	181.4	33.74	4.09	16.35	130,670.	246.1	997.4	12.0
Receiver Pressure 100 Lbs. Gauge.									
150°	.02095	Final Temperature below 32° F.							
190°	.05601	53.83	13.11	5.74	84.59	66,740.	55.4	93.2	32.8
230°	.14130	116.4	16.18	5.96	49.14	80,630.	87.8	200.7	24.2
270°	.37395	157.4	22.24	5.97	25.74	106,460.	147.9	478.4	17 1

(C. R. WEYMOUTH. 2-10-99.)

Then the total heat supplied by boiler becomes,

$(B_1T_1U_1$ per lb. of air$)=cv\,(t_1-t_0)+n\,(q_1+p_1-q_2)+144\,Ap_0\,(v_1-v_0-no)$.

Substitute,

$$p_0=pa_1+ps_1\ ;\ s-o=w.$$

$144\,Apv=ART$; and neglecting p_0no,

$$B_1T_1U_1=Q+cv\,(t_1-t_0)+n\,(\lambda-q_0)-+AR\,(T_1-T_0)+144\,Aps_1v_0.$$

Since, $cv+AR=cp$, specific heat at constant pressure,—BTU becomes,

$B_1T_1U_1=cp(t_1-t_0)+n(\lambda_1-q_0)+144\,ps_1Av_0$ and when $t_0=60°$ F.,

$$B_1T_1U_1=.2375\,(t_1-60)+n\,(\lambda_1-28.1)+.4762\,ps_1.$$

The weight of steam per pound of air is calculated from the formulæ,

$$ns_1=v_1\ ;\ \text{or}\ n=\frac{RT_1P_1}{144\,(p_1-ps_1)}.$$

The final temperature and work of expansion are calculated by the general formula given above.

The thermodynamic efficiency of reheating is the ratio of the heat equivalent of increased work to the heat added.

Table II. gives the approximate results of calculation for this method of reheating.

Air and water are both assumed to have a temperature of 60° F. before heating.

Table III. shows the relative merits of the two systems, both being on the basis

Table III.

T	A	B	C
150°	27.8	21.9	
170°	21.3		
190°	19.2	19.5	32.8
210°	16.5		
230°	14.7	14.8	24.2
250°	13.2		
270°	10.8	12.0	17.1

T.—Initial Temperature of Mixture.

A.—Thermodynamic Efficiency of Reheating Steam fed in pipe near motor.

B.—When passed through boiler at 60 lbs. gauge.

C.—When passed through boiler at 100 lbs. gauge.

of 60° temperature of feed, air and water.

It is interesting to note that the efficiency of dry reheating is 38% at 60 lbs. gauge, and 45% at 100 lbs. gauge, with adiabatic expansion.

Traction and Auto-Mobile

Annual Meeting of the American Air Power Company.

The annual meeting of the stockholders of the American Air Power Company, which had twice been adjourned, was held recently, when A. A. McLeod, president of the company, tendered his resignation, he to continue, however, as a director. He will be succeeded by H. H. Vreeland, of the Metropolitan Street Railway Company, which is largely interested in the American Air Power Company. Directors were elected as follows: William L. Elkins, Thomas Dolan, H. H. Vreeland, J. H. Hoadley, A. A. McLeod. With the exception of Mr. Vreeland, who succeeded Gen. G. E. P. Howard, resigned, these had served on the previous board.

Following is a report read by the retiring president, Mr. McLeod:

"Mention was made in the last annual report of the contract your company made with the Metropolitan Street Railway Company for the establishment of a plant and the equipment of twenty cars to be put on the Twenty-eighth and Twenty-ninth street line.

"This line was put into operation in July last, and the cars have been in successful operation since that time. In August last, under the terms of the contract, the line was turned over to the Metropolitan Street Railway Company for the purpose of making an operating test, which is now being made.

"The cars are giving excellent service,

the traffic on the line has increased very largely, and the result of the operation thus far is very gratifying, and may be considered a commercial success.

"It may be said that when the cars were first put into practical operation some few mechanical defects were discovered which could not be foreseen, as is likely to be the case with every new device, but the short experience already had has enabled your engineers to make such improvements as were necessary, and as a result the latest improved car which has been put on the line is giving great satisfaction.

"I am of the opinion that the method of propelling street cars by compressed air, the patents for which are exclusively owned by your company, is on the eve of such success as will prove very gratifying and valuable to your shareholders, and enables me to turn over to my successor in such a way as to secure for your shareholders the greatest possible advantage.

"As the Metropolitan Street Railway Company is the largest individual holder of your capital stock, and as it has a very large street car mileage in this city which is now operated by horse-power, naturally the first work of importance for your company will be the equipment of these lines, and as Mr. H. H. Vreeland, the president of that company, has kindly consented to take the presidency of your company, I believe it will be greatly to the interest of your shareholders to elect him president.

"I, therefore, decline a re-election, and while I regret that I feel it incumbent upon me to do so, owing to the pressure of other business, the affairs of your company are so well established and will be conducted in the future by so able and experienced a man as Mr. Vreeland, that I am sure your interests will not only not suffer, but be greatly enhanced. As a member of the board I shall continue my interest in the company."

Mr. Vreeland says that his election to the presidency of the American Air Power Company, which has been operating the cross-town cars on Twenty-eighth and Twenty-ninth streets by compressed air, would not affect the policy of the company materially. The American Air Power Company, he said, has always been in close touch with the Metropolitan, being practically under the control of that company since its formation. The present equipment, used only on the Twenty-eighth and Twenty-ninth street lines, will be increased as soon as possible, and air motor cars will be placed on Thirty-fourth street.

The problem of the downtown cross-town lines, he said, has not been taken up as yet. The success of the air power cars was assured, declared Mr. Vreeland, and the defects which at first appeared in the mechanical equipment had been remedied.

Air Motor a Success.

The following interview was recently published in certain New York papers relative to compressed air street car traction.

Mr. H. H. Vreeland, president of the Metropolitan Street Railway Company, who was recently elected president of the American Air Power Company, said today that the Hardie and Hoadley-Knight types of air motors, both of which are controlled by the latter corporation, have demonstrated their success from a practical standpoint.

"One car of the Hardie type is expected here very shortly," said Mr. Vreeland. "We have had cars of the Hoadley-Knight system in successful operation on our Twenty-eighth and Twenty-ninth street line in this city. The only cars of the Hardie type we had were in operation in Chicago, with the exception of this one, which happened to be up at the Rome works, where they were built. We ordered it sent here. Four more have been ordered. When they arrive we shall run them with the other cars on the cross-town line. The one car ought to be here and in operation within the next two weeks.

"The Compressed Air Motor Company of Chicago, before the consolidation of interests which took place in 1897, and which brought the control of both the Hardie and the Hoadley-Knight patents into the hands of the American Air Power Company, received territorial rights in Illinois and Wisconsin from one of the sub-companies which went to form the American Air Power Company. That contract, on territorial right, was recog-

nized in the consolidation. The American Air Power Company is a stockholder in that corporation."

"What particular advance in mechanism has made the use of air motors practicable?" he was asked.

"They have been operated for years abroad," said Mr. Vreeland. "The highest pressures they have used there, however, have been 400 to 600 pounds. The power has been used for mine work, for an interlocking signal system and for other purposes, but always at low pressures. Operation abroad has always been successful, according to the conditions there. They have a pipe-line by the side of the track and stop cars at intervals to charge the reservoirs. A delay of two to three minutes is the result. It is not at all noticeable in European street railroading, but American methods hardly admit of such delays. Of course, the higher the compression of air, the farther cars can be operated on a given amount of space in the reservoirs."

"Then the American Air Power Company controls improved apparatus for compressing air?" the reporter asked.

"Yes. We have engines here that will compress air up to 3,000 pounds. We have had twenty cars of the Hoadley-Knight type running on the Twenty-eighth and Twenty-ninth street line for the past five months, and they have been a commercial and operative success. My idea was to bring the two types into operation under identically the same conditions and determine whether one was better than the other, or whether combinations could be made between the two which would bring about a more perfect design."

"Is it the purpose of the Metropolitan Company to adopt air motors to a large extent on its lines?" the reporter inquired.

An Air Wagon.

The picture on the frontispiece is an air wagon constructed by Chas. D. P. Gibson, and is the property of the Air Vehicle Company, of New York. The engine is of the usual 2-cylinder type, and weighs 36 pounds, and has several special features in its construction. It is adapted for the use of air or steam, as may be required. With the use of air it has a storage capacity of six cubic feet, which could be increased without material addition to the total weight of the wagon, which is with the present capacity 670 pounds.

With air as a power appliance for reheating the air is used. The air is stored at a pressure of 2,500 pounds per square inch, and reduced to an initial cylinder pressure of 150 pounds by an ingenious arrangement of reducing valves, which are under the control of the operator and allowing the working pressure to be regulated as required.

On a recent trial on a bad road this wagon was operated with a consumption of 60 cubic feet of free air per mile. The condition of the road was much below the average, and the trail was not one which would give the most economical results in the use of the power, yet under these conditions it would be seen that the storage has capacity to run the wagon 20 or 30 miles. And as it is estimated that air can be compressed for less than 4 cents per 1,000 cubic feet, it is believed that it will prove a desirable and economical power for propelling omnibusses and delivery wagons which have a definitely determined route to travel. Its freedom from odor or visable final exhaust makes it the ideal power to use. The engines of this wagon operates equally well with steam, and buyers are to be supplied with steam wagons or air wagons as they may desire.

With steam the power is supplied by a small steam boiler, the fuel is gasoline, the supply of which is automatically controlled by the boiler pressure, and the water feed operated by the engine and under the control of the person operating the wagon.

The steam wagon has no radical departures in use of steam in engine or boiler, but special care and consideration has been given each detail that it will do its work with a minimum of attention and reliability in operation. Particular attention has been paid to simplicity of details, as well as to their durability, and with steam as a power, the range of the wagon's distance of operation, or the distance that it can be run, is unlimited.

We hope at an early day to give more fully the details of this company's wagons.

Pneumatic Tools

Drilling and Riveting on the Elevated Railroad, New York.

In connection with the strengthening of the girders on the Manhattan Elevated Railway, which has lately been effected, it was found that considerable economy could be obtained by the use of pneumatic tools, and it was in consequence decided to install a gasoline driven air compressor, together with a pneumatic riveter and a pneumatic drill. The air compressor capacity being limited, the question of the consumption of air of the tools used became of considerable importance, and a riveter made by the Q. & C. Company and a drill made by the Standard Pneumatic Tool Co. were chosen as those satisfying the conditions.

The test for air consumption was made by pumping up the receiver to a certain pressure, then cutting off the compressor and driving the tools entirely from the air contained in the receiver while certain operations were performed. By noting the drop of the pressure the air consumption of the tool while doing the observed work could thus be ascertained by the well known formula of the number of cubic feet of free air contained in the resorvoir at different pressures. Thus, supposing the reservoir had a capacity of 10 cubic feet and contained air at a gauge pressure of 90 pounds: This would correspond to an absolute pressure of 105 pounds, or 7 atmospheres absolute, and the number of cubic feet of free air contained in the reservoir would therefore be 70. At a pressure of 30 pounds the same reservoir should be filled with air at a pressure of 3 atmospheres absolute and the cubic feet of free air contained therein would therefore be 30. If in running a tool the pressure were reduced from 90 to 30 pounds, there would therefore have been used 40 cubic feet of free air. While this test is not absolutely correct, since pneumatic tools are usually designed for a pressure of about 80 to 90 pounds, and would consequently work less efficiently at the lower pressures to which the reservoir might be reduced, it offers a fairly accurate comparative test of the different types of tools.

With respect to the riveter: The rivets driven are ¾-inch in diameter in 13-16-inch holes, and in driving 25 rivets the average consumption of free air per rivet was 5 cubic feet of free air. In driving this number of rivets the pressure was reduced considerably, but this may be taken as a fair indication of what is required for this size of rivet with a riveter such as used on this work. When the time of riveting is taken into account occupied by these machines, viz.: about 6 to 7 seconds with this size of rivet, the air consumption as measured corresponds very closely with that figured by the cylinder capacity of the riveter, which is 50 cubic feet of free air per minute for continuous working. The measured consumption, 5 feet in 6 or 7 seconds, is slightly less than this, which is easily accounted for by the fact that there is a certain amount of wire drawing through the ports admitting air to the cylinder at the high velocities at which these machines operate.

The makers of this appliance have devoted considerable attention to the question of pneumatic riveting and have found that the weight of the hammer employed in riveting is an important point with regard to the quality of the work done. If a rivet is hit with a light hammer, irrespective of its velocity, the rivet is flattened out on the end that is hit, but not upset or thickened near the head. In other words, the effect is as shown in the attached sketch, Fig. 1. If hit with a slightly heavier hammer, the flattening process is less marked and there is a greater tendency to upset the rivet throughout its entire length, the action being somewhat as is shown in Figure II. If hit with a very heavy hammer in proportion to the size of the rivet, the head is flattened but slightly, while the rivet is evenly upset throughout its entire length. For these reasons they have adopted a weight of hammer in their pneumatic riveting machines that is practically the same as used in hand riveting.

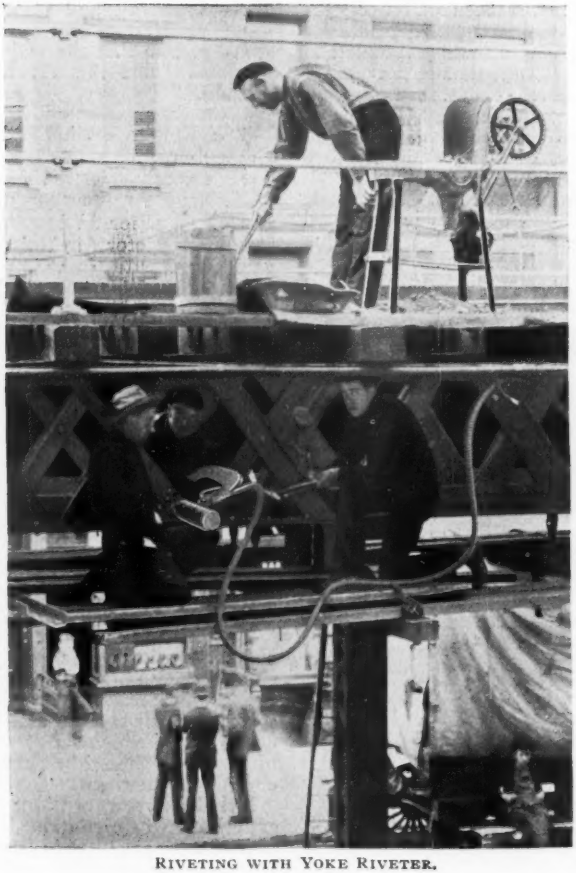
In a machine for driving ¾-inch or ⅞-inch rivets, the weight of the hammer is 4½ pounds; while in the pneumatic riveter for rivets up to 1¼-inch diameter, a hammer is used weighing 7¾ pounds. With such weights of striking hammers as these, the rivet is not merely flattened

DRILLING AND RIVETING ELEVATED R. R. STRUCTURE.

only on the head, but thoroughly upset throughout its entire length, and if properly heated, will fill the holes completely, doing work that is equal in quality to that effected by pressure machines.

In pneumatic riveting, it is important that the rivet should be rather differently heated to the way that is usual for hand riveting. They require to be better heated throughout their length and only slightly hotter on the end that is to be driven. The reason for this is, that the best part of the upsetting is done in the first few blows and that if the metal is much softer at the end than toward the head, the harder metal near the head cannot be upset through the softer. Excessive heat is not required, but simply a more even heat throughout the length of the rivet than in hand riveting. Then again, if the holes are not good, and the rivet when put in is not square with the plate, the riveter should be skewed over so as to drive the rivet back concentric with the hole before hammering is commenced. If the riveter is started working on such a rivet, the first few blows tend to bend the rivet into a still worse shape and it is then impossible to make the head true with the remainder of the rivet.

Dies also require attention: The right size die must be used, or rather the proper length of stock used on the rivet to thoroughly fill the dies, as machine riveting is different from hand riveting in this respect. It is rather similar to pressure work, and if the rivet does not properly fill the die, the edge of the die coming on the sheet prevents the rivet from being thoroughly upset. The Q. & C. Company have given considerable attention to this and other details, such as valves and snap catches, methods of working, etc., and have developed their



RIVETING WITH YOKE RIVETER.

tools to a point where they are ready to guarantee their machines to drive rivets as large as 1¼-inch in diameter and thoroughly upset them in the sheets, giving results equal to pressure riveting. These tools are all of the valveless type in which the piston controls the admission of air above and below it, and no valve is used except that to turn the air on and off. Such a machine is exceedingly simple in construction and it can be taken apart for cleaning or inspection by the men employed on the work, without the necessity of engaging the services of a skilled mechanic. The construction of these machines admit of the use of a pipe yoke on any gap, some of them being made as large as 10 feet without the slightest trouble. Such a yoke is, of course, exceedingly light, and such riveters are not only especially adaptable to work where the riveter has to be moved about without extensive staging, but frequently it can be used where a machine entailing a heavy or girder form of yoke would be entirely out of the question.

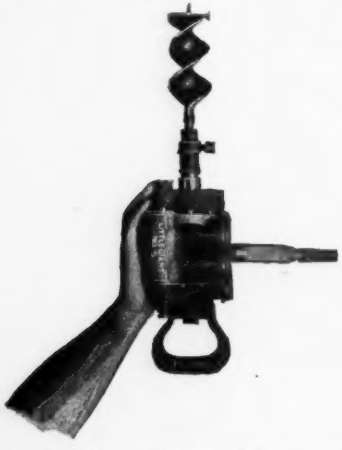
FIG. 1.

FIG. 2.

FIG. 3.

There has recently been placed on the market by the Standard Pneumatic Tool Co., a new pneumatic tool, designated as the "Little Giant" Pneumatic Reversible Boring Machine No. 5, designed especially for work around railroad car shops. Being very compact and light in weight, which permits of its being easily handled and operated, and very efficient in all classes of boring into wood. It is made of steel throughout, and can be operated in a bath of oil, as exhaust does not come in contact with working parts.

One of the principal features of this machine is that it is reversible, as by a slight turn of the handle it can be reversed running at full speed, withdrawing the auger instantly. The advantages of this is apparent, particularly when boring holes in cars. It is geared to run at a high rate of speed, and is so constructed that it will last for a long time without getting out of repair. It has double-



balanced piston valves which cut off at ⅝ of full stroke, consequently is very economical in the use of air. The weight of this machine is 12 pounds, and is capable of boring into wood up to 3½ inches in diameter to any depth. An effort has been made to make this a superior pneumatic boring machine, and at the present time the claim is made that the success obtained under exhaustive tests and comparisons proves everything claimed for it.

When a firm takes pleasure in sending machines on trial to any one desiring to test its efficiency, and will pay the express charges both ways if it fails to meet with their approval, and also guarantee the same against repair for one year, it is quite certain that the claims can be substantiated, and this the above company will do.

The Empire Engine and Motor Co. of Orangeburg, New York, report that they have recently received orders from the U. S. Navy Yards at Brooklyn, N. Y., and Norfolk, Va., for an installation of several Pneumatic Motor Air Hoists and Drills in each place.

They have also just filled a large order for Pneumatic Motor Air Hoists for the Brooks Locomotive Works, Dunkirk, N. Y.

COMMUNICATIONS.

Under this heading will be published inquiries addressed to the Editor of COMPRESSED AIR. We wish to encourage our readers in the practice of making inquiries and expressing opinions.

We request that the rules governing such correspondence will be observed, viz., all communications should be written on one side of the paper only; they should be short and to the point.

Ottawa, Canada, Dec. 13, 1899.

Editor Compressed Air:

Permit me to point out one or two circumstances in connection with Mr. Dickerson's method, set forth in his article in the current number of your interesting periodical, for measuring the latent heat of liquid air, which seems to me to depart further than should be permitted from accurate measurement.

Mr. Dickerson mentions that the liquid experimented on contained a greater proportion of oxygen than does air and that he neverthless disregarded the higher boiling point which this circumstance would naturally involve in view of its comparative negligibility. He was undoubtedly justified in doing so as, unless the oxygen was very much out of proportion, the rise in temperature could not be more than about a single Celsius degree. I must point out, however, that, although he states the boiling point of liquid air correctly in terms of Fahrenheit degrees as —312 degrees, he has taken the temperature of boiling oxygen instead of that for boiling air when stating the thing in Celsius degrees. That is to say, he has taken —181.4 degrees C. instead of —191.4 degrees. This is an error to start with of no less than 18 degrees F. His results are stated in

Fahrenheit units. If he had worked from the Fahrenheit temperature, which he took correctly, he would have been all right but, instead, he used the French units and then worked them back into English.

This error, however, while regrettable and one which vitiates his results clear through, can readily be corrected for and the experiment recalculated without repeating any of the work. The chief points which I wish to criticise are fundamental in the method.

What occurred when the metal pieces were immersed in the liquid air was not at all a boiling off of air, but of an atmosphere containing but a few per cent. of oxygen, and the heat rendered latent by this occurrence was the sum of the latent heat absorbed by the two constituents, which was quite different from the latent heat of the same weight of air. One might as well endeavor to estimate the latent heat of a mixture of water and alcohol by a method which caused a volatilisation only of a fraction of the whole mass and which, in consequence, caused a vaporation of the alcohol out of all proportion to the ratio of its presence in the original mixture.

This serious error would throw out the result or not depending on whether or not the latent heat of nitrogen deviates much from that of oxygen. I am not aware whether it does so or not, but, as Dewar's figure for the latent of oxygen is 144 B. T. U., and as Mr. Dickerson's, when corrected for the error above pointed out in connection with the boiling point of air, becomes, for the latent heat of a mixture of oxygen and nitrogen of indeterminate composition, 129 B. T. U., it will be obvious that there is a probability of a pretty considerable divergence.

Of course, what he should have done was to arrange a method in which the whole of the liquid would be evaporated or else to measure the amount of heat rendered latent in evaporating any weight of a mixture which could thereafter be analyzed and working the result by algebra against another result from the gasification of a mixture of oxygen and nitrogen of widely different (and known) composition.

Respectfully yours,

Ernest A. Le Sueur,

Electrical and Chemical Engineer.

Dec. 12, 1899.

Editor of "Compressed Air":

I have a 24 x 18 power exhauster which operates satisfactorily at 40 R. P. M. with a port opening 20 x 1⅛ inches.

With 27-inch vacuum at what speed could this machine be operated to advantage? This machine has a simple slide valve, no lap, with eccentric 90 degrees ahead of crank.

If we desired to make a 9-16-12 D4 steam driven exhauster, at what speed do you think it would operate? It seems to me to be a question of velocity of gas through a variable port opening. If you can give me any idea it would be appreciated.

Thanking you for any information which you may give me, I am,

E. W. King, M. E.,

Deane Steam Pump Co., Holyoke, Mass.

The data given by Mr. King is somewhat limited, and it is possible that we have not obtained a proper understanding of his purposes. To begin with the engine described is a practical steam engine with a slide valve which is rigidly connected with moving parts and has a definite cycle which insures a certain relation between the piston and the valve at all times. The action is the reverse of the ordinary steam engine, in that air is admitted in what is usually the exhaust and is discharged from the steam chest, which is always the inlet in the usual engine. We will assume the piston at one end of its stroke just starting back, and we will assume that air is taken in for a full stroke on one side, and discharge for a full stroke on the other side. In the ordinary compressor of which this is the reverse, the valves remain fully open or fully closed, as the case may be, during the entire stroke. With a slide valve just described, the ports area is constantly changing from a very small opening through all ranges to the full size of the ports and again closing. However, the velocity of the moving piston, which is drawing in air on one side and expelling

it on the other, is also changing. These two changes are, therefore, coincident, and properly related, that is, as the port opening of the inlet or outlet side of the cylinder is increasing or decreasing in area, the velocity of the inflowing or discharging air is increasing or decreasing as the case may be. It is usually true that these complimentary changes are not identical, and that the valve may close at a more rapid rate than the piston slows down, which causes an increased friction at the port; this point will be considered later.

For the present we will take the liberty of assuming the velocity of flow of air and the change of valve area as parallel variables. Another point to be considered is, that the pressure tending to fill the inlet side of air cylinder is that of the atmosphere or 15 pounds. Now it would seem that the limiting speed of such an engine would be for any given case that speed which would cause the air to flow through the full open port, neglecting now the resistance of pipes, elbows, etc., at the same velocity which air would have if allowed to flow through an orifice in a receiver, where the pressure is 15 pounds, and the outside pressure practically nothing, or from a receiver pressure of 30 pounds to an outside pressure of 15 pounds.

For practical purposes, however, it is better to assume a velocity of flow through the port of 100 ft. per second, which is the figure used for calculating port openings for steam engines.

To make this clearer take the exhauster mentioned by Mr. King.

The port area is $20 \times 1\frac{1}{8} = 22\frac{1}{2}$ sq. ins. or 0.156 sq. ft. $100 \times 60 \times 0.156 = 936$ cu. ft. per min.

The volume of the cylinder, 24×18 ins., is 4.75 cu. ft. Dividing 936 by 4.75, the volume of the cylinder, gives 197 strokes or 98 revolutions per minute.

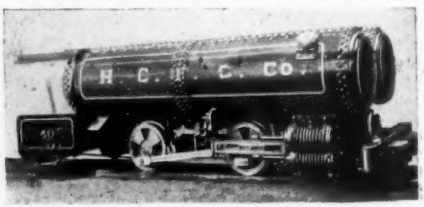
Air Jets

The Merrill Pneumatic Pump Co., 141 Broadway, New York, have issued a very neat booklet, entitled: "Only a Pump, You Say." It discusses the advantages of the Merrill Displacement Pump, and any one acquainted with this excellent apparatus knows that the claims they make for it are not in any degree exaggerated.

These pumps are used in a large number of places, and the R. P. Moore Milling Co., Princeton, Ind., report that they use one for bringing water one and one-quarter miles.

Other abstracts of testimonials are given that are valuable in that one of the examples may fit your case. Send for the booklet, it will repay you.

No. 17, a pamphlet just received, is a "Record of Recent Construction" in locomotives, and although the above is not devoted to compressed air locomotives, the Baldwin Locomotive Works, Philadelphia, who issue it, are builders of successful types of compressed air mine locomotives, of which the above is a cut.



This locomotive was built for the H. C. Frick Company and is equipped with the Vanclain compound cylinders, and it has shown excellent results. A former pamphlet gives a number of illustrations and general dimensions of these engines, both single expansion and compound.

Interesting experiments are being made by Mr. John S. Thurman, consulting mechanical engineer of St. Louis, Mo., with his perfected apparatus for cleaning carpets and other fabrics. A company known as the General Compressed Air House Cleaning Co. has been incorporated, with extensive capital for developing this field, and operations will begin at once.

Mr. Arthur L. Rice, of Brooklyn, N. Y., Junior Member of the Society of Mechanical Engineers, at the December, 1899, meeting of that society read an interesting paper on the Compression and Liquefaction of Gases, treating particularly with the liquefaction of air. The paper illustrates and describes the apparatus used by Tripler and others.

The paper was supplemented by an exhibition of the physical properties of liquid air and its effects upon substances. The familiar experiments of freezing alcohol, mercury, rubber, meat, tin, roses and other material were made.

Colonel Ashley W. Cole, Chairman of the New York State Railroad Commissioners, recently declared in a *Mail and Express* interview that compressed air is the power of the future for street cars. He gave the cost of one strip of underground trolley conduit in New York as $600,000 a mile, and the average cost as $100,000 a mile. He was very emphatic in the conclusions he had reached and seemed impressed by the advantages of an independent motor system of street cars as against trolley or other systems, and he especially mentioned the factor of safety in storage tubes which are tested up to 6,500 pounds to the square inch whereas they are never charged beyond 2,500 pounds.

The doors of the open-hearth steel furnaces of the Alabama Steel and Shipbuilding Co., Ensley, Ala., of which there are ten in number, each of fifty tons capacity, are operated by compressed air.

PATENTS GRANTED NOV., 1899.

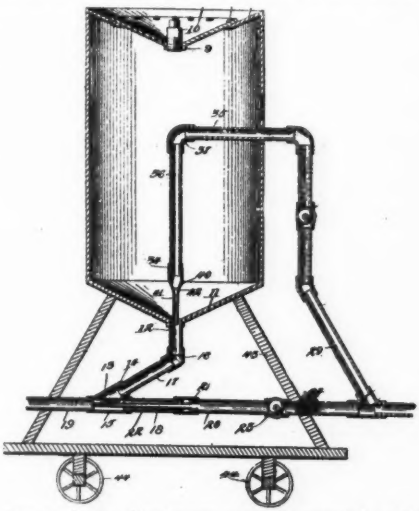
Specially prepared for COMPRESSED AIR.

636,256. **APPARATUS FOR SIMULTANEOUSLY PURIFYING, COOLING AND REGULATING MOISTURE OF AIR.** Elmer Gates, Chevy Chase, Md.

The herein-described method or process of treating air, which consists, essentially, in moving the air through a tube or cylinder with a whirling or rotary motion about the axis of the tube, such whirling motion being interrupted by eddies, simultaneously subjecting the air to the cooling and purifying action of small bodies of water, and subsequently removing moisture from the air while it is moving in contact with a dry and relatively cold surface

636,279. SAND-BLAST. James M. Newhouse, Marble Cliff, Ohio.

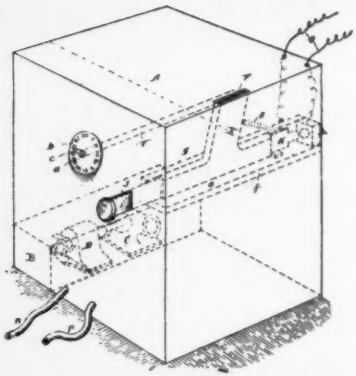
A sand-blast, comprising a sand-reservoir having an outlet opening, a siphon in operative relation to said opening and adapted to create suction therethrough from the



reservoir, a discharge-pipe connected with said opening, a second siphon in the discharge-pipe, and adapted to create suction from the reservoir-opening, and to establish pressure at the outlet of the discharge-pipe, means for supplying a fluid under pressure to the siphons, and means for regarding the fluid supplies independently.

636,308. DEVICE FOR INFLATING PNEUMATIC TIRES. John F. Wilson, Jetmore, Kan.

In a pneumatic-tire inflater the combination of a case having an air-chamber therein, means for inflating said air-chamber, means communicating with the said air-chamber adapted to be connected to said



tires, a coin-case having a chute, sliding bars at the lower end of said case having their inner ends separated a sufficient distance to permit coins to pass between, whereby the operation of bars causes inflating means to be set in motion, a lever provided with a weight upon one end adapted to slide thereon, and having its opposite end arranged to engage with one of sliding bars, for overcoming the pressure of weight by the air-pressure from chamber.

636,343. PNEUMATIC VALVE. Herman Leineweber, Chicago, Ill., assignor of one-half to Charles H. Trego, same place, and John E. Roberts, Evanston, Ill.

As a new article of manufacture, a pneumatic valve, composed of a single piece of leather cylindric in cross-section from a point between its center of length and one end and rectangular in cross-section throughout the remainder of its length, the rectangular portion being pierced centrally and longitudinally by a narrow slit, substantially as described.

636,372. BEARING FOR THROWING-WHEELS FOR PNEUMATIC ELEVATORS. George W. Williamson, Indianapolis, Ind., assignor to the Pneumatic Elevator and Weigher Company, same place.

636,414. COTTONSEED CONVEYOR. John T. Moore, Yantis, Tex., assignor of two-thirds to Kimbro T. Denton and Robert S. Blythe, Sulphur Springs, Tex.

636,446.—COW-MILKER. Nels. H. Norby, Cooleysville, Minn.

636,459. COMPRESSOR FOR ICE-MACHINES. Eliel L. Sharpneck, Chicago, Ill., assignor to the Ideal Refrigerating and Manufacturing Company, Colorado Springs, Col.

In a refrigerating-machine, the combination with the compressor-cylinder and the gas return and discharge conduits, of an eduction port in the cylinder-head, communicating with the discharge conduit, an inwardly-closing valve at said port, a piston in the cylinder, and means for operating the piston to move the same to the cylinder-head approximately without clearance, comprising a toggle-lever mounted to rock at one of its arms on a fulcrum and operatively connected at its other arm with the piston, and toggle-lever driving means comprising a crank-shaft geared to the toggle-lever, to flex the same to one side and produce the suction stroke of the piston, in the movement of the crank to one dead-center, and to extend the toggle-lever to a dead-center, and produce the discharge-stroke of the piston, in the movement of the crank to the other dead-center, and interrupt movement of the piston at the end of the discharge stroke for a prolonged period, whereby the seating of the eduction valve is effected during such interruption

636,460. SAND-BLAST MACHINE. George S. Slocum, Newport, R. I.

The combination of a blast-conduit a nozzle having a slot or elongated crevice adapted to form a sheet-like jet, a forebay, a baffle-plate having a lateral crevice or crevices communicating with a reservoir chamber, and said reservoir chamber

The combination of a blast-conduit connection N; a nozzle Z Z' adapted to form a jet; a swiveling valve-chamber C provided with valve-seated orifices leading to said nozzle and to a by-pass respectively; means for locking said chamber at angular adjustments; a shell B, having a forebay, a baffle-plate, and marginal ports communicating said forebay with a reservoir-chamber; a table T provided with supports and a port A; a chimney having lateral crevices adjoining said nozzle; a sand-receptacle, a housing or cover K having an opening; a movable, dust-tight lid k fitting said opening; mechanism for supporting and moving a piece of stencil-covered work within range of said nozzle; and treadle P, spring Q, pitman P^s and stem S, for operating said valves,

636,643. AIR-COMPRESSOR. Samuel A. Donnelly, Chicago, Ill.

In an apparatus of the class described, the combination with a pair of compression-chambers, a body of liquid, a reversible pump adapted to alternately exhaust the liquid from one and discharge it into the other of said chambers, and means for operating said pump, of a slide, a pair of pistons connected thereto and exposed to the pressure produced by the pump, a weight, a swinging arm by which the weight is carried, a connection between the arm and slide, and means controlled by the slide for changing the relations of the power and load,

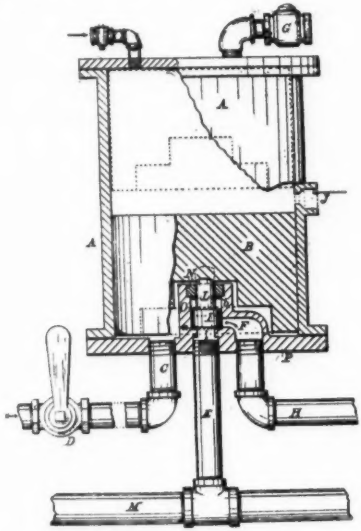
636,651. AIR-PURIFIER FOR REFRIGERATORS. John C. Fleming, Philadelphia, Pa., assignor of one-third to Angus J. Macdonald, New York, N. Y.

In an air-purifier, the combination of a refrigerator, a casing located within the latter and having foraminous walls, an air-chamber formed between said casing and one of said walls, charcoal supported between the latter, and inlet and outlet pipes extending from said casing through the sides of said refrigerator and communicating with said air-chamber, said pipes serving to support said casing within said refrigerator.

636,670. PNEUMATIC COTTON-HANDLING APPARATUS. Dudley E. Jones, Little Rock, Ark.

The combination of a main conduit, and means for delivering the cotton therefrom, a fan for drawing the cotton through said conduit to the point of delivery, said fan being of larger capacity than said conduit at its intake end, means for supplying a supplemental volume of air to the fan during the movement of the cotton, a dust-flue leading from the fan, whereby more air is forced through the dust-flue than is drawn in with the cotton and through the cotton-conduit, and means for delivering cotton-seed into said dust-flue.

636,770. TIME-VALVE FOR PNEUMATIC RAILWAY-SIGNALS. Frank L. Dodgson, Rochester, N. Y., assignor, by mesne assignments, to the Pneumatic Railway Signal Company of West Virginia.



The combination, in a time-valve for pneumatic railway-signals, of the cylinder A, the piston B, a pipe connecting with said cylinder for operating the piston, the lower cylinder-head having the valve-casing O, the time valve in said casing disconnected from said piston and having the stem L guided in said casing and extending within the cylinder, and suitable connecting-piping.

637,021. AUTOMATIC AIR-BRAKE HOSE-COUPLING. Howard E. Parkinson, Spartanburg, S. C

637,065. PNEUMATIC ROCKER. Otto Anderson, Stillwater, and Andrew W. Anderson, Lake Elmo, Minn.

A rocker formed in its under surface with the longitudinal recess or seat 3 terminating in the end sockets 4 and provided with the detent-grooves 5 in its sides, in combination with the pneumatic tube 6 terminating at its ends in the conical points 7 and provided at its sides with the detent-flanges 8, which tire is held in position when inflated.

637,144. HYDRAULIC AIR-COMPRESSOR. Lee E. Mitchell, Boston, Mass.

A hydraulic air-compressor, comprising a tank having air inlet and discharge valves and water inlet and discharge valves, a rod connected with both water inlet and outer valves to operate them, a rock-shaft having an arm connected with said rod, a sleeve journaled upon the rock-shaft and having a counterweight and lever-arms connected therewith, bent arms carried by the sleeve and extending on opposite sides of the arm upon the rock-shaft, said bent arms being separated so as to engage the rock-shaft arms at the extremities of their swing, and a float connected with the lever arms and adapted to overcome the counterweights

637,516. PUMP FOR COMPRESSING AIR OR GAS. Henry E. Ludwig, Erie, Pa.

The combination in an air or gas compressor, of a cylinder and a piston operating therein, a valve-chest and valve operating therein for controlling the air or gas being compressed in said cylinder, and having a passage or passages therein adapted to connect the ports at both ends of the cylinder at or near the commencement of each return stroke of the piston therein for equalizing the pressure in the ends of the cylinder, and means for admitting liquified air or gas into said passage or passages in the valve.

637,659. COMPRESSION OF AIR AND UTILIZATION THEREOF. Edward E. Pettee and John J. McCutchan, New York, N. Y., assignors, by mesne assignments, to the Automatic Air Carriage Company of New York.

The method of compressing air and utilizing the same for motive purposes which consists in preheating and moistening the air and compressing it in that condition and maintaining the heat of compression of the dense moist air throughout its passage from the compressor to the motor

The method of utilizing in a motor, the heat of compression developed in an air-compressor supplying said motor, which consists in maintaining the compressed air at the temperature developed in the air-compressor cylinder during its passage into the motor

637,660. UTILIZATION OF COMPRESSED AIR FOR MOTIVE PURPOSES. Edward E. Pettee and John J. McCutchan, New York, N. Y., assignors, by mesne assignments, to the Automatic Air Carriage Company, of New York.

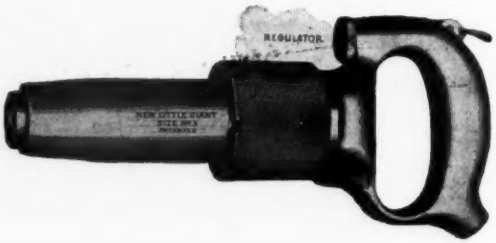
637,661. COMPRESSION OF AIR AND UTILIZATION THEREOF. Edward E. Pettee and John J. McCutchan, New York, N. Y.

"LITTLE GIANT"

PNEUMATIC TOOLS AND APPLIANCES

DURABLE EFFICIENT

DRILLS
BORING
MACHINES
BLOW-OFF
COCKS



HAMMERS
FLUE
ROLLING
MACHINES
RIVETERS

Light in weight and economical in use of air.

SENT ON TRIAL.

GUARANTEED AGAINST REPAIR FOR ONE YEAR.

STANDARD PNEUMATIC TOOL CO.,

MANUFACTURERS OF

PNEUMATIC TOOLS AND APPLIANCES OF ALL KINDS.

NEW YORK, LONDON, **MARQUETTE BLDG., CHICAGO, ILL., U. S. A.** PARIS, BERLIN, BRUSSELS.

COMPRESSED AIR MOTOR COMPANY.

COMPRESSED AIR MOTORS

An Independent Motor, under quick control, noiseless, at reasonable cost, of high efficiency, free from danger and all objectionable features. The most economical system in cost of installation, operation and maintenance ever offered to the public. Thoroughly tested, both Winter and Summer, and endorsed by prominent engineers.

Cars in size and appearance the same as electric or cable cars, the floor being no higher from rail. No paying space occupied by the air storage or mechanism, all being placed under the car floor.

RUN AT ANY SPEED DESIRED. OVERCOME GRADES AND SHARP CURVES EASILY. EQUIPPED WITH NOISELESS AIR BRAKES.

Can be recharged with air in less than two minutes, and constructed to run any desired distance. Motors and entire load spring supported. Cars can be introduced one at a time on the track of any railway, steam, electric, cable or horse. Cars of this type performed a daily service of 81½ miles each upon 125th Street, New York City, for one complete year, during which time they ran 32,159 miles, and carried 188,854 cash fares.

COMPRESSED AIR MOTORS FOR STREET, SUBURBAN AND ELEVATED RAILWAYS.

COMPRESSED AIR MOTOR CO.,

45 BROADWAY, NEW YORK.
1033 MONADNOCK BLOCK, CHICAGO, ILL.

AMERICAN VEHICLE COMPANY.

H. D. COOKE, President. J. D. CAMPBELL, Engineer. A. H. COOKE, Secretary.

ROOMS 137-145,

45 BROADWAY, NEW YORK CITY, N. Y.

An association of engineers and business men has been formed to put on a commercial basis for all purposes the best form of automobile.

With few exceptions this question has been dealt with in this country as a fad, and while the fact has been recognized and confessed by all, that there is a broad field for automobiles, no systematic effort appears to have been made to develop their uses. There has been lots of talk of applying them to business wagons, but little has been done in that direction. Many schemes have been devised by what might be termed amateur mechanics, who have claimed much, but who have really accomplished but little.

The men forming this Company have no pet theories or pet devices, but desire to go into the market with the best power and machine obtainable, applying it to practical work. They recognize the fact that there are a number of automobile engines in the market now, and that some of them may be developed to do the work planned.

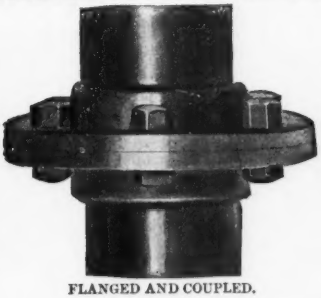
The full development of this industry will not be accomplished by talking. The machines must be put into practical use. This will develop defects for which remedies can be applied.

Arrangements are already made to acquire rights for steam and gas automobiles, and experiments are being made with an air wagon, and this combination is ready to consider any form of engine or power that promises to give the results aimed at.

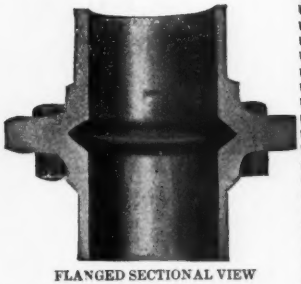
SEAMLESS STEEL TUBING FOR HIGH PRESSURE COMPRESSED AIR.

TUBES UPSET AND FLANGED FOR COUPLING.

UPSET SECTIONAL VIEW.



FLANGED AND COUPLED.



FLANGED SECTIONAL VIEW

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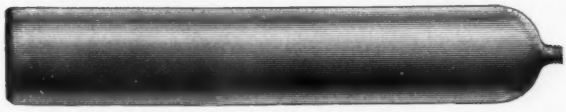
For Storage of Gases and Compressed Air.



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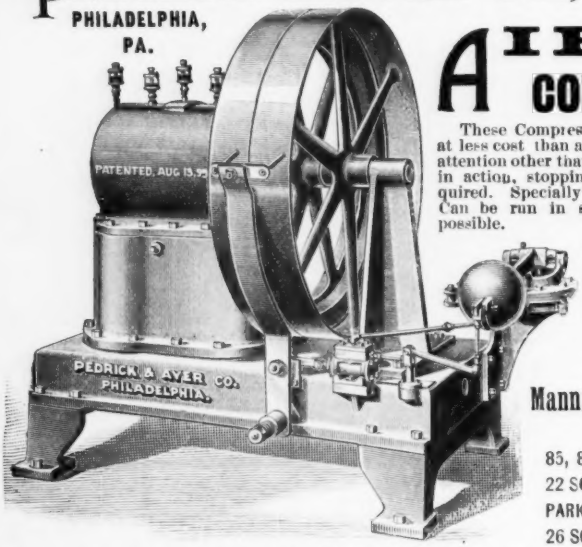

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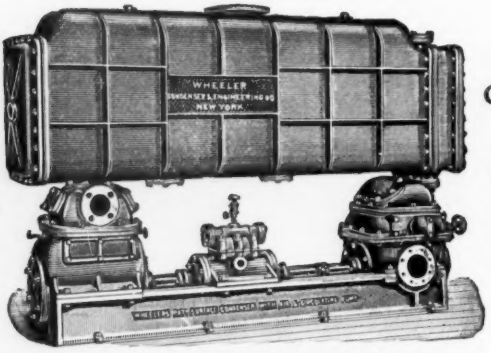

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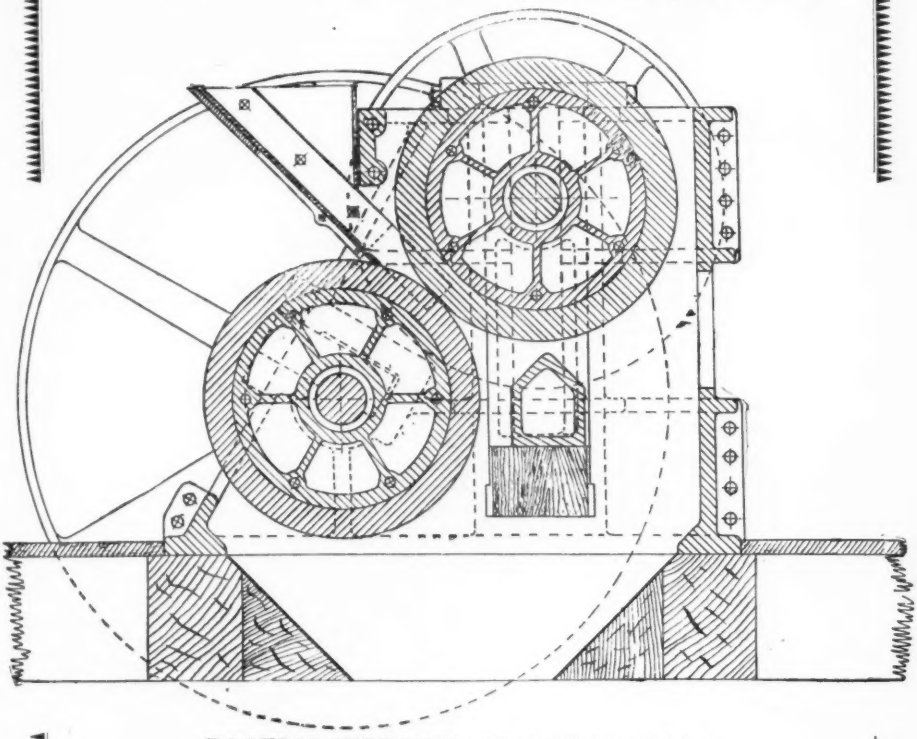

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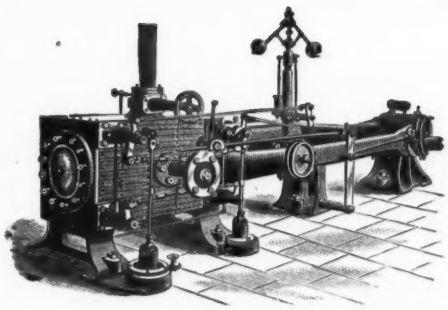

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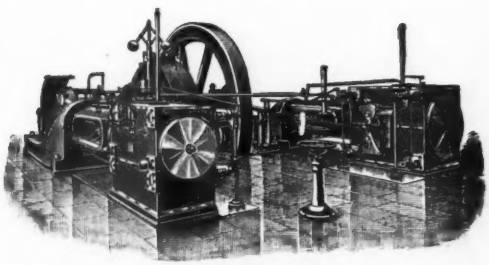

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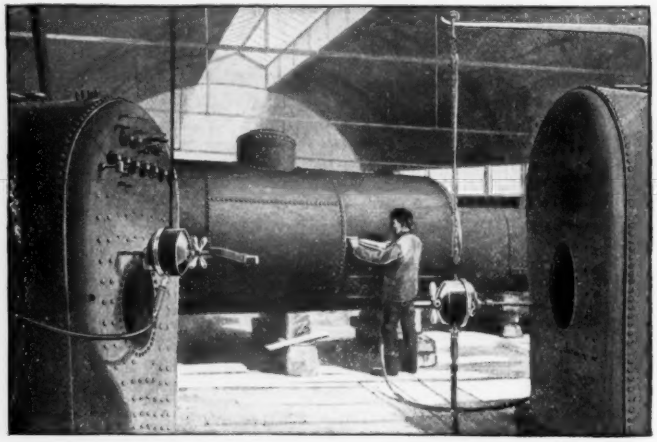

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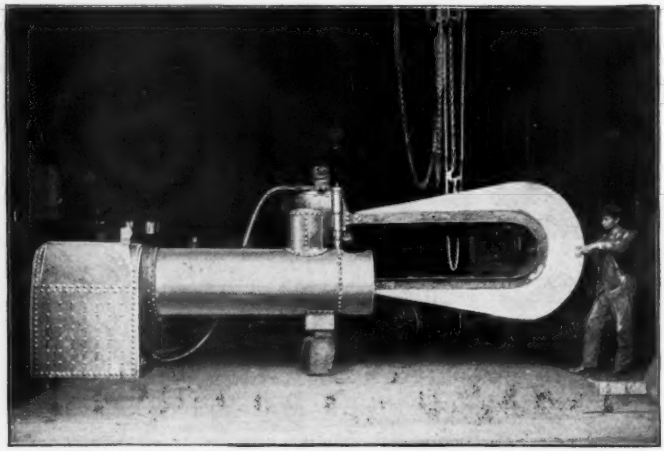

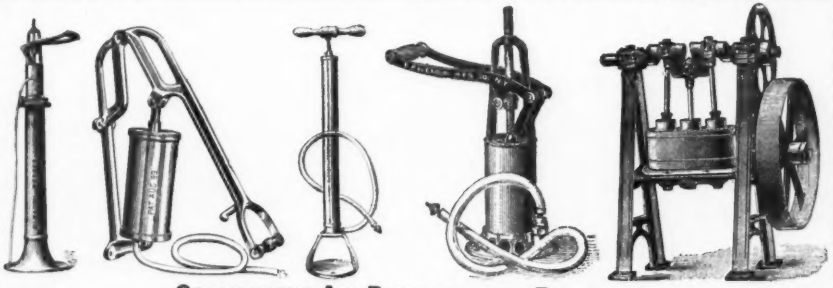

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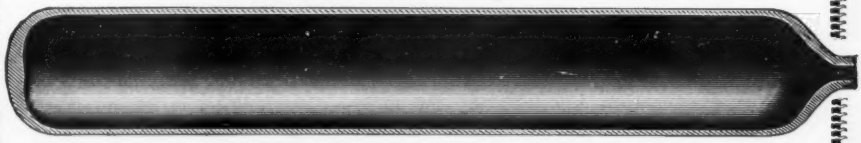

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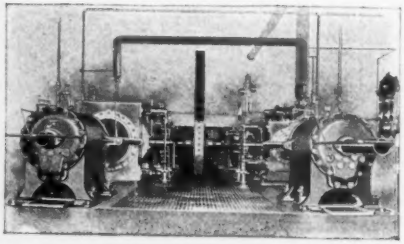

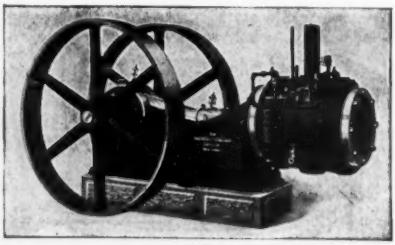

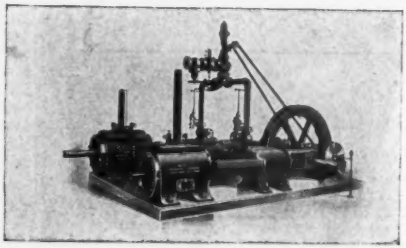

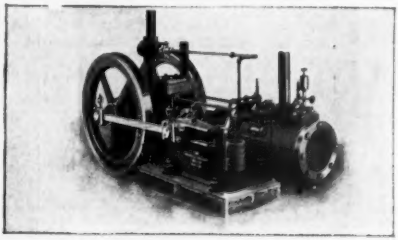

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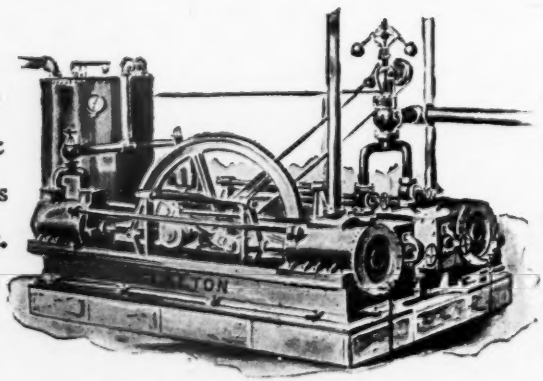

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